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Abstract

Despite 150 years of use, forensic entomology is still an emerging field of forensic science and is yet to find an undisputed place in the legal proceedings on account of the absence of sufficient background data and also due to the dearth of professional forensic entomologists. At present, very few entomologists are engaged in this discipline and a lot of useful evidence for estimation of PMI goes waste due to shortage of base-line data and adequate expertise. A large base-line data on the taxonomy, zoogeographic distribution, biology and ecology of insects involved in the decomposition of dead animals needs to be established to avail maximal achievement of the objective evidence of estimating time since death. A thorough knowledge of certain fauna of different geographical areas is required for utmost use of insects in forensic investigations. It needs to be realized that a forensic entomologist can be a valuable adjunct to the forensic pathologist since the former can reasonably support and defend latter in his estimation of PMI by interpreting the insect evidence either on the basis of cadaver fauna or on the basis of age of developing insects.

Keywords: Entomology; Forensic; Death; cadaver; Postmortem Interval; arthropods;

Introduction

Forensic or medico-criminal entomology is a major field of forensic sciences that primarily deals with determination of time, place and mode of death from application of the study of insects and other arthropods to legal issues such as murder, suicide, sexual molestation, child-neglect and abuse, chemical intoxication, contraband trafficking etc [1]. Forensic entomology is inexorably a scientific discipline that interprets the information related to death using insect specimens as silent witnesses in order to provide data not available by using the routine methods of classic pathology [2]. A forensic entomologist therefore, by identifying the stages of development of insects or arthropods and by analyzing the data for interpretation of insect evidence, can provide significant evidence in cases of death where human body or its remains are colonized by insects. He / She can determine the period of invasion of cadavers by insects keeping in view the variables like temperature, humidity etc., from their different developmental stages like egg, larva, pupa and adult so as to estimate the time since death or the post mortem interval (PMI) based on the developmental rates and successional ecology of specific insects that feed on the cadavers.

An unnatural death demands an adequate investigation that needs the joint efforts and co-operation of experts from different fields i.e. pathologists, entomologists, anthropologists, crime scene investigators and many other medico and non-medico experts [3]. Co-operation among these professionals, particularly a close interaction of forensic entomologists and forensic pathologists, can lead to a better understanding of the evidence recorded at any crime scene and at autopsy. Information provided by forensic pathologist and co-investigators can be fundamental for interpreting insect evidence and determining the period since commencement of insect activity based on either the composition of cadaveric fauna or on the age of developing insects [4]. This article aims to review various aspects of forensic entomology so as to insist for a coordinated approach of various professionals like entomologists, investigators

and pathologists involved in the practice of death investigations and to encourage a high level competency in forensic entomology as well as to promote and establish common standards of this practice with reference to collection and presentation of entomological evidence.

History

The first recorded use of insects in crime investigation dates back to 13th century from a Chinese village [5]. During medieval times, the correlation between maggots on a cadaver and oviposition of adult flies was not recognized, though the realistic and detailed illustration of corpses containing maggots was not unusual [6]. At the beginning of 19th century it was noted that the flies were attracted by corpses at a very early stage of decomposition. First application of forensic entomology in a French courtroom in 1850 can be viewed as a breakthrough for this discipline [7]. Krahmer [8], described the opportunities & problems associated with using insects for estimation of PMI. Yovanovich [9] and Megnin [10] were the first forensic experts who attempted to evaluate the insect succession on corpses, properly establishing the science of forensic entomology. During the last three decades, the utility of medico-criminal entomology in death investigations has been largely documented by several case studies in western countries mainly the Europe & the US. Nuorteva et al [11] were among the first to use forensic entomology for determination of PMI in Europe. By the beginning of 21st century, forensic entomology came to be accepted as an important forensic tool in many countries [12-17].

Common Insects on Cadavers

Besides their ecological importance in decomposition, the insects particularly blowflies represent important tools in criminal investigations serving as a biological clock in measuring the time since death for weeks or even for months. From forensic-entomological point of view, the necrophagus species and their predators & parasites are the important insects to be attracted to the body immediately after death even within minutes [18]. Insect specimens may be treated as physical evidence just like blood-stains, hair, fingerprints or any other biological material [19] and hence should be processed as evidence at crime scene, at autopsy and at the laboratory [20, 21]. Various necrophagus insects are selectively attracted by the decomposing status of the carrion and form complex communities or biocenosis within necrophagus or sarcophagus species and their predators, parasites and parasitoids competing each with one another. Knowledge of distribution, biology and behavior of insects found in, on, or nearby a cadaver can assist many types of forensic investigations by providing information on when, where and how under certain circumstances a crime was committed or a person died.

Sarcophagidae, calliphordiae, staphylinindae, muscidae, dermestidae etc., are the common families of insects of forensic importance. Since forensic pathologists are unlikely to be in a position to identify these insect species, so there arises a need for inclusion of a forensic entomologist in the crime investigation team along with crime scene investigators, lab technicians etc.

Standards and Guidelines for Analyzing the Crime Scene for Entomological Evidence:

Some internationally accepted standards and approaches for collecting, packaging and transmission of entomological evidence is required which will enable the forensic entomologists to collect and provide samples of high quality allowing for subsequent application of appropriate entomological expertise. A broad range of professionals like entomologists, crime scene investigators, forensic pathologists, anthropologists and botanists could be engaged in collection of entomological evidence despite being unfamiliar with the dispersed methods and techniques of forensic entomology [4]. Specific collecting techniques and standard procedures in different environments at death

scene [22, 23], at autopsy [24], and in the laboratories [20] have been developed to enhance the recovery of insect specimens. The procedure for the forensic entomological analysis or crime scene includes

- Visual observations and notations
- Collection of climatological data
- Collection of specimens from the body and the surrounding area (up to 6m from the body) before removal of remains
- Collection of specimens from directly under and in close proximity (I meter or less) after removal of remains.

The natural orifices, traumatic wounds of the cadavers and eyes are the preferred sites of oviposition by the insects. The other places of interest are corpse-substrate interface, under the body, in the pleats of clothes and pockets, shoes etc. of the deceased on the carpet or bag in which the body might have been wrapped for storage or for transportation.

Visual observations include the observation of type of habitat, the number and kinds of flying, resting and crawling insects, major infestations associated with the body and the surroundings, insect predators, exact position of the body, insect activity within 3-6m of the body, any unusual, naturally occurring or man-made phenomenon altering the body etc.

As the length of insect life cycle is influenced by temperature, precipitation and humidity of the environment, so the climatological data in estimating PMI is quite crucial. Ambient, ground, body-surface, under-body interface maggot mass and soil temperatures are procedurally noted. Weather data of scene (when victim was last seen up to discovery of body) may be collected from the nearest meteorological station.

Entomological specimens should be collected from the area surrounding the body before its removal and also from directly under and in close proximity to the remains after removal. Intensive search of the area up to at least 2 meter away from the body is required for the insects that might have dispersed from the body neglecting the other possible insect specimens

All the insect specimens of different shape and size and from everywhere on and around the corpse should be preserved in vials containing 70-95% ethanol so that their morphological and molecular identification is made easy. The living specimens are either caught in insect nets or are collected in vials lined with moistened tissue paper which allow entry of air while at the same time preventing the escape of the said insect specimen. These samples should then be transferred to the laboratory for rearing of different stages of the insects. The living adult insect specimens are maintained under optimum temperature conditions. Remainants such as pupal skins, empty puparia or beetle faeces (which represent previous insect activity) should be stored in dry condition in vials with 70-95% ethanol. Thus, a systematic and quality assured approach should exist for collection, preservation, packaging and transportation of entomological evidence not only to prevent contamination or destruction of the evidence but also because forensic entomology deals with living organisms to be treated with care [6].

Eggs, Larvae, pupae and adults of the insects from and around the human remains should be collected using sticky traps with a slow drying adhesive substance. Rearing of insect specimens up to adult stages makes identification easier, thus giving vital clues to the PMI estimation. The live specimens should be placed in incubators with known temperature and humidity levels and should be watched for hatching of eggs, pupariation or eclosion of insects and time duration of each activity should be recorded.

Reconstructing the death scene conditions as closely as possible and collection and interpretation of entomological evidence

associated with dead bodies should preferably be collectively done by the forensic entomologist and pathologist correlating circumstantial information and the findings noted at the crime scene and at the autopsy [17]. The forensic entomologist be responsible for determining the period of insect activity based on composition of arthropod community on the cadaver or on the basis of age of developing immature insects according to all the variables affecting insect invasion of remains and their development.

Applications of Forensic Entomology

The techniques devised in forensic entomology during recent past allow experts to collect strong entomological evidence and provide very useful information not only in a death investigation including time since death, season of death, geographical location of death, movement or storage of the remains after death, time of decapitation or dismemberment, submersion interval, use of drugs but even more in linking a suspect to the scene of crime, in child-neglect and sexual molestations or identification of suspects. The case histories constitute the most fascinating reference in forensic entomology literature as they show different applications of this discipline in medico-legal investigation but individual case reports are valuable in this subject as a composite review of such cases from one region of the world can introduce more understanding concerning their nature and type of evidence that occurs in a particular region.

Estimation of PMI

An accurate estimation of time since death (PMI) is an important aspect of every death investigation (especially in suspicious deaths) particularly for highly decomposed or skeletonised bodies, to reconstruct the events and circumstances of death, to link a suspect to the victim and to establish the credibility of statements made by the expert witnesses [4]. It is not only useful in criminal cases but also in civil cases for insurance & inheritance where such estimate may have profound judiciary implications [25].

The forensic pathological methods of PMI determination are viable only in the early post-mortem period but when the human remains are found beyond 48-72 hrs, weeks or even longer after death, such methods to a degree become unreliable and inaccurate. In that case, the entomological evidence associated with and around the corpse become more important and can indicate the time elapsed since death up to a period of several weeks or even months depending upon the insect species involved and climatic conditions of death scene [6] and such estimate is said to be more precise than the forensic pathologist's estimate [25].

Basically, the age of the adult insects of a particular species found on the corpse is estimated on the basis of life cycle & life history of that species. But a more precise way of estimation of time since death is the rearing. The non-hatched eggs found on corpses are reared up to adult insects with succession of different stages and time period for each stage is noted.

Another important biological phenomenon occurring on the cadavers is succession of organisms thriving on different parts in a fairly predictable sequence which can be used in estimating time of death if the body has been lying around for some time. As for example beetles specializing on bone will have to wait until bone is exposed and predatory rove beetles will have to wait until blowflies arrive and lay eggs.

Precautions must be taken for the correct collection and identification of insects at death scene and at autopsy and in the application of knowledge of arthropod life cycle in indigenous fauna or the entomofauna associated with the cadaver to determine the age of specimens collected [16,26, 27]. Exact species identification of the insect specimen is the essential step in estimating the age of the specimen which differs in biology, growth rates

and upon the ambient temperature. The entomological estimation of PMI is based on the age estimation of immature stages of necrophagus flies corresponding to the time when insect colonization of the corpse took place.

In early post-mortem period, the estimate is based on direct age assessment of the oldest specimens developed on the body but in the late post-mortem period, the estimate is based on the composition of arthropod community relating to expected successional patterns. Before ageing the specimens, correct species identification with reliable identification keys is necessary by comparing the stage of oldest immature specimens sampled from the cadavers and the surroundings with known or reared species from the same zoogeographical area at known temperature.

Entomotoxicology

Entomotoxicology is the analysis of carrion feeding insects to detect toxic substances and to investigate their effect on the insect development [28]. Forensic entomology can assist the pathologists in narcotic or drug intoxication of the cadavers as the insect specimens may serve as alternate reliable specimens for examination of toxicologically relevant substances in the absence of appropriate sources such as tissue, blood or urine in highly decomposed or badly skeletonised bodies [28-32]. The insects encountered or their larvae may reveal toxicological assessment of the cause of death [28, 32], as they feed on the corpses and may sequester drugs and other toxicants, otherwise ingested by the deceased person. The insect specimens incorporate and bio- accumulate chemical metabolites of drugs into their own tissues such as barbiturates, cocaine, amphetamines and even poisons. The insect tissues or even remainants of pupal / larval specimens can be macerated and processed to detect these substances even after several years of death [33, 34]. But the ingested drug or toxicant can influence or modify the development of the necrophagus flies, thus causing a risk of calculating incorrect PMI. So before using the insect specimens for PMI determination, the forensic entomologist should be aware of the extent of effects of drugs and toxins on their rate of development [30] or on their delayed invasion of the tissues [35].

Secondly, the absence of drug in larvae may not indicate that drug was not present in the cadaveric tissues [36 – 38]. Thus chemical analysis of maggots found on, in or around the cadavers can reveal the presence of specific drugs / chemicals / poisons, particularly in cases where no human tissues are available for investigation. Further research focusing on the bioaccumulation and metabolism of drugs in necrophagus insects and their effects on their rate of development is required [6].

Estimation of movement of the corpse

Insect specimens found within corpses may also indicate the movement of the corpse [25, 39, 40]. If an insect is found on a cleverly concealed body, it means that body has been moved there from somewhere else. It has been documented that some flies are heliophlic whereas others prefer shady conditions and some are synanthropic whereas others are not.

Insects are also found on stored products like narcotics and drugs which are usually smuggled out form a producer state. If insects are found with narcotic drugs, then a study of world distribution of different insects can determine the origin of such contraband trafficking.

DNA and Forensic Entomology

A specialized taxonomic knowledge of insects species is must for their correct morphological identification but only a very few forensic pathologists are available who are expert to identify the forensically relevant insect specimens up to species level even with the aid of baseline identification data and key-models

[6]. So species identification based on genetic examination such as DNA analysis is an option.

DNA of human blood can be successfully extracted from a carrion blood-feeding insect specimen collected from a crime scene which might have fed on the cadaver. The presence of DNA of suspect within the insects at a known location within a definable period of time may establish a link between the victim and the crime. A case has been reported where the DNA recovered from the blood of one the insects collected from the crime scene matched to that of murder suspect [41].

Conclusions

The science of medico-criminal entomology is dynamic and is in its emerging stage, so its basic standards and techniques are subject to continual revision based on advances in scientific knowledge and methodology. A death investigation usually requires co-ordination between a number of multidisciplinary professions but a close interaction of forensic entomologists with forensic pathologists is strongly recommended. The forensic entomologist can be a valuable adjunct to the forensic pathologist since the former can reasonably support and defend latter in his estimation of PMI by interpreting the insect evidence and determining the commencement of insect activity either on the basis of composition of cadaver fauna or on the age of developing insects. Entomological methods are statistically more reliable mainly after 72 hours after death and are superior when compared to other prevalent forensic pathological methods based on post-mortem changes in tissues. A baseline data model for calculation and handling of data is crucial for the credibility of the discipline. More systematic studies related to flies and insects' infestation on human remains should be conducted by forensic entomologists during the routine medico-legal examination of skeletal human remains on a worldwide basis

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